# Early history of ISNA

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# Early History of ISNA

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**Abstract.** The International Symposia on Nonlinear Acoustics, now referred to as ISNA, have convened regularly since 1968, bringing together scientists and engineers to report and discuss the latest developments in this branch of nonlinear physics. The fact that this series of symposia is still going strong after more than four decades is testimony that nonlinear acoustics has established itself as a distinct, important, and vibrant field of research. In this paper we take a look back at the early years of ISNA to recall how it all began and trace the evolution of the symposia into their current form.

**Keywords:** ISNA, history
**PACS:** 43.05.Dr

## INTRODUCTION

The International Symposia on Nonlinear Acoustics (ISNA) is a series of international meetings on nonlinear acoustics that began in 1968. The symposia have evolved independently of any particular acoustical society or other professional affiliation. While the ISNA receive various levels of financial support from scientific organizations, they are organized entirely by local researchers in nonlinear acoustics where the symposium is held. Overall administration is limited to an International Organizing Committee, made up primarily of chairs of previous ISNA. Its principal function over the years has been to select future venues for ISNA.

This article is about initiation of the series, its early growth, and eventual emergence in the once-every-three-years format in place today. Also presented are statistics on the size of the symposia.

## THE BEGINNINGS

To place in context the motivation for holding what is now recognized as the first International Symposium on Nonlinear Acoustics in 1968, one must consider the state of nonlinear acoustics in the years leading up to this meeting. Prior to 1950, research in nonlinear acoustics was primarily theoretical and apart from a few investigations of spherical waves, the analyses were usually restricted to plane waves. Euler, Poisson, Riemann, and Earnshaw pioneered the development of exact solutions for waveform distortion in ideal fluids, while Rankine, Hugoniot, Stokes, Rayleigh, and Taylor attacked the problem of describing shocks. Not until the 1950s were serious attempts made to model nonlinear beams of sound. The development that was initially most consequential for modeling nonlinear sound beams was Sir James Lighthill's exact reformulation of the three-dimensional equations of motion for an ideal fluid. Although derived to describe the generation of sound by turbulence, Lighthill's equation was seized upon by Peter Westervelt to model the nonlinear interaction of two intersecting sound beams.

A watershed moment in nonlinear acoustics came in June 1960 when two papers were presented back-to-back at the spring meeting of the Acoustical Society of America in

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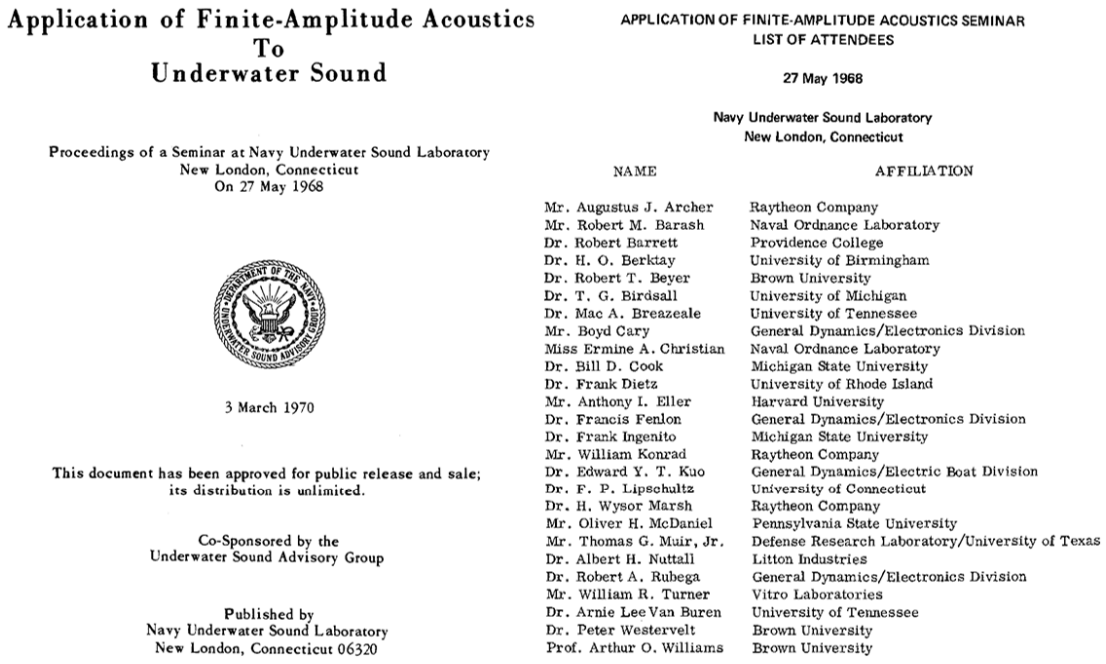

Application of Finite-Amplitude Acoustics
To
Underwater Sound

Proceedings of a Seminar at Navy Underwater Sound Laboratory
New London, Connecticut
On 27 May 1968

3 March 1970

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APPLICATION OF FINITE-AMPLITUDE ACOUSTICS SEMINAR
LIST OF ATTENDEES

27 May 1968

Navy Underwater Sound Laboratory
New London, Connecticut

| NAME | AFFILIATION |
|---|---|
| Mr. Augustus J. Archer | Raytheon Company |
| Mr. Robert M. Barash | Naval Ordnance Laboratory |
| Dr. Robert Barrett | Providence College |
| Dr. H. O. Berktay | University of Birmingham |
| Dr. Robert T. Beyer | Brown University |
| Dr. T. G. Birdsall | University of Michigan |
| Dr. Mac A. Breazeale | University of Tennessee |
| Mr. Boyd Cary | General Dynamics/Electronics Division |
| Miss Ermine A. Christian | Naval Ordnance Laboratory |
| Dr. Bill D. Cook | Michigan State University |
| Dr. Frank Dietz | University of Rhode Island |
| Mr. Anthony I. Eller | Harvard University |
| Dr. Francis Fenlon | General Dynamics/Electronics Division |
| Dr. Frank Ingenito | Michigan State University |
| Mr. William Konrad | Raytheon Company |
| Dr. Edward Y. T. Kuo | General Dynamics/Electric Boat Division |
| Dr. F. P. Lipschultz | University of Connecticut |
| Dr. H. Wysor Marsh | Raytheon Company |
| Mr. Oliver H. McDaniel | Pennsylvania State University |
| Mr. Thomas G. Muir, Jr. | Defense Research Laboratory/University of Texas |
| Dr. Albert H. Nuttall | Litton Industries |
| Dr. Robert A. Rubega | General Dynamics/Electronics Division |
| Mr. William R. Turner | Vitro Laboratories |
| Dr. Arnie Lee Van Buren | University of Tennessee |
| Dr. Peter Westervelt | Brown University |
| Prof. Arthur O. Williams | Brown University |

**FIGURE 1.** Front cover of the proceedings (left) of, and list of non-NUSL attendees (right) at, ISNA-1.

Providence, Rhode Island, by two physics professors at Brown University, where the meeting was held. In the first paper, Westervelt presented his theory for the parametric array [1], and in the second Robert Beyer and his student J. L. S. Bellin, together with Westervelt, presented experimental confirmation of Westervelt's theory [2]. The first truly practical application of nonlinear acoustics had thus appeared on the scene, the production of a narrow low-frequency sound beam by the nonlinear interaction of two collinear high-frequency sound beams. However, despite its remarkable properties, the far-reaching implications of the parametric array were not fully appreciated in the United States until the publication of a paper in 1965 in Journal of Sound and Vibration by Orhan Berktay [3], an electrical engineering professor at University of Birmingham in the United Kingdom.

Berktay's work caught the attention of researchers at the Navy Underwater Sound Laboratory (NUSL) in New London, Connecticut, who were also working on nonlinear acoustics. One of the researchers, Robert Mellen, subsequently organized a seminar that was held at the Lighthouse Inn in New London on 27 May 1968, now recognized as the first International Symposium on Nonlinear Acoustics (ISNA-1). Mellen wrote in the preface to the proceedings of this symposium that "Recent developments involving high power sonar transducers...made it evident that it would be highly beneficial to hold a symposium to exchange ideas among those active in finite-amplitude research." Not counting NUSL employees, 26 scientists and engineers attended the symposium (see Fig. 1). Berktay was the centerpiece of the symposium and the only attendee not then working in the United States. Five papers were published in the proceedings of ISNA-1: "Nonlinear Acoustics" by Beyer, "Nonlinear Interactions between Acoustic Waves in Liquids—Possible Applications" by Berktay, "Progress in Nonlinear Acoustics" by Bill Cook, "Nonlinear Acoustics Research at NUSL" by Mellen and David Browning, and "Two Experiments with Nonlinear Acoustics" by Wysor Marsh. A list of all ISNA proceedings, together with symposium dates, locations and chairs, appears in the Appendix.

In attendance at the New London symposium was Thomas (Tom) Muir, then a graduate student working at Applied Research Laboratories (at that time named Defense Research Laboratory) at University of Texas at Austin (ARL:UT). Excited by what he learned at the New London symposium, Muir returned to Texas and together with fellow graduate student Joseph (Joe) Blue conducted experiments on the parametric array at an ARL:UT test facility on Lake Travis, located near Austin. The results of these experiments were submitted for publication in Journal of the Acoustical Society of America (JASA) [4], and a preprint wound up in the hands of Robert Mellen. Impressed by the work, Mellen contacted Muir and suggested that he convene a second symposium on nonlinear acoustics at ARL:UT. What is now recognized as ISNA-2 was then held in Austin in November 1969, 18 months after ISNA-1.

Financial support for ISNA-2 from ONR (Office of Naval Research) and NUSL reflected the continued focus on sonar applications, but the subject matter covered at ISNA-2 had broadened beyond what was covered at ISNA-1. While half of the 10 papers in the proceedings are directly related to the parametric array, including the papers by Westervelt and Berktay, the other five cover the history of nonlinear acoustics, simple waves in multidimensional gas flow, nonlinear waves in ducts, parametric oscillations in an ultrasonic resonator, and scattering of sound by sound. As at ISNA-1, Berktay was the only attendee at ISNA-2 not employed in the United States.

The symposia became truly international with the meeting now recognized as ISNA-3, which was chaired by Berktay and held at University of Birmingham in April 1971. The countries represented at ISNA-3 were Canada, Denmark, Norway, United Kingdom, and United States. Fourteen papers were published in the proceedings, half of which were still on the parametric array. Norway accounted for three of the papers in the proceedings, which was published by the British Acoustical Society.

What is now recognized as ISNA-4 was not a symposium in the traditional sense. ISNA-4 was a series of three special sessions on nonlinear acoustics organized by David Blackstock at the April 1972 meeting of the Acoustical Society of America in Buffalo, New York. The three sessions were named (preceeded by the words "Nonlinear Acoustics") I: General and Air Acoustics (11 presentations), II: Underwater Applications (12 presentations), and III: Solids and Liquids (6 presentations). Rather than a proceedings, the archival record of this symposium comprised the 29 oral presentation abstracts published in the general meeting program as a volume of JASA. Less than half (11) of the presentations were on the parametric array. Also noteworthy at this symposium was the appearance of nonlinear waves in solids as a distinct topical area of nonlinear acoustics.

Numbering of the symposia commenced with what is now recognized as ISNA-5, which was held in Copenhagen in August 1973. The chair of the symposium was Leif Bjørnø, who proclaimed in the preface to the proceedings that this symposium was the fifth in a series. Thus only in hindsight were the first four ISNA officially recognized as such, at least by number if not yet by name. ISNA-5 marked the appearance of cavitation and bubble dynamics as a major topical area within the scope of the symposia; a quarter of the 47 papers in the proceedings were in this area.

The modern name of the symposia—International Symposium on Nonlinear Acoustics—made its first appearance at ISNA-6, which was held in July 1975 at Moscow State University and chaired by R. V. Khokhlov. The proceedings contains 60 papers, and, as noted by Khokhlov in the preface, for the first time a substantial number of the papers were on nonlinear waves in solids. As at ISNA-5, cavitation and bubble dynamics appeared prominently. In terms of scope and format, ISNA-6 was quite similar to modern ISNA.

## LATER YEARS

Figure 2 shows the numbers of papers published in the proceedings for each ISNA according to the year the symposium was held (as opposed to the date of publication). When the publication of record consists only of a book of extended abstracts, as for ISNA-7 (Blacksburg, 1976) and ISNA-9 (Leeds, 1981), or as abstracts at an ASA meeting, as for ISNA-4 (Buffalo, 1972), these instead were counted. Another caveat is that papers published in the proceedings of ISNA-16 (Moscow, 2002) that were associated with two satellite symposia not related to ISNA were excluded from the count.

Perhaps most noticeable in Fig. 2 are the two large spikes for ISNA-11 (Novosibirsk, 1987) and ISNA-16 (Moscow, 2002), which are the latter two of the three ISNA held in Russia (or, more accurately prior to 1992, the Soviet Union), the first being ISNA-6 (Moscow, 1975). The level of participation reflects the very extensive Russian activity in nonlinear acoustics. However, although it is now known that the parametric array was being developed in the former Soviet Union during the 1960s at the same time it was being developed in the United States and Great Britain, ISNA did not have Russian participation until the Copenhagen symposium in 1973, when Khokhlov and V. A. Krasilnikov from Moscow State University attended. Up until the 1990 ISNA in Austin, at which 12 of the 92 papers published in the proceedings had Soviet authors (with no cancellations of the corresponding oral presentations), significant participation by the Soviets had occurred only at ISNA-6 and ISNA-11. It should also be noted that whereas 60 papers appeared in the ISNA-6 proceedings, which was published in 1976, and this is the paper count reflected in Fig. 2, the 1975 meeting program lists 109 scheduled oral presentations, clearly a record at that time.

Figure 2 reveals a roughly linear growth of ISNA participation over the years. Beginning with the Paris ISNA in 1978, the symposia have been held at regular three-year intervals up until the present, Tokyo ISNA in 2012. The latter had to be postponed a year because of the Fukushima nuclear disaster in 2011.

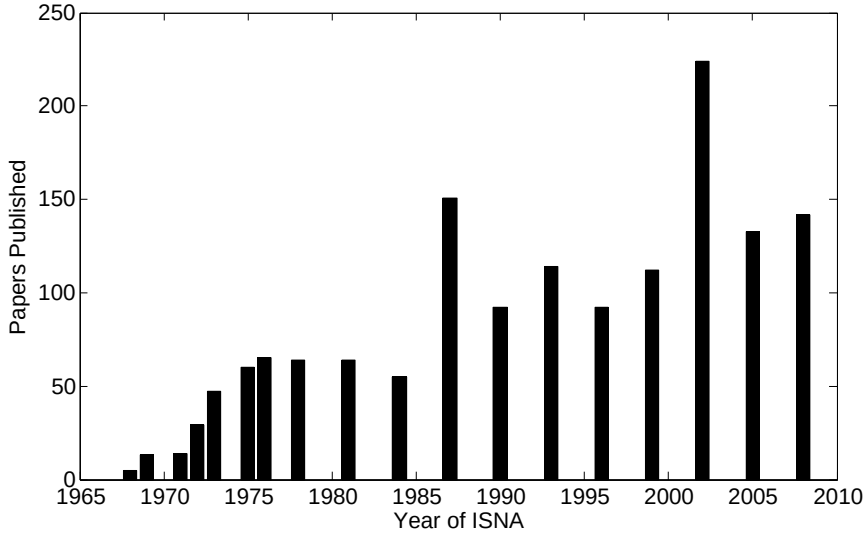


**FIGURE 2.** Numbers of papers published in proceedings of ISNA by year the symposium was held. When the proceedings consists of only abstracts (1972, 1976, 1981), those were counted instead.

## CONCLUSION

The success and overall continuous growth of ISNA for more than four decades reflect the importance of nonlinear acoustics as a scientific discipline and the enthusiasm of the researchers working within this discipline.

## REFERENCES


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3. H. O. Berktay, "Possible exploitation of non-linear acoustics in underwater transmitting applications," *J. Sound Vib.* **2**, 435–461 (1965).
4. T. G. Muir and J. E. Blue, "Experiments on the acoustic modulation of large-amplitude waves," *J. Acoust. Soc. Am.* **46**, 227–232 (1969).


## APPENDIX

## DATES, LOCATIONS, AND PROCEEDINGS OF PAST ISNA

ISNA-1 27 May 1968
New London, Connecticut, USA
R. H. Mellen, Chair

*Application of Finite-Amplitude Acoustics to Underwater Sound*, Proceedings of a Seminar at Navy Underwater Sound Laboratory on 27 May 1968, edited by R. H. Mellen (Navy Underwater Sound Laboratory, New London, Connecticut, 1970) (AD 707 721, NUSL Report No. 1084, USAG Report No. 69-6).

ISNA-2 10–11 November 1969
Austin, Texas, USA
T. G. Muir, Chair

*Nonlinear Acoustics*, Proceedings of a Conference Held at Applied Research Laboratories, The University of Texas at Austin 10–11 November 1969, edited by T. G. Muir (Applied Research Laboratories, The University of Texas at Austin, Austin, Texas, 1970) (AD 719 936).

ISNA-3 1–2 April 1971
Birmingham, UK
H. O. Berktay, Chair

*Proceedings of Symposium on Nonlinear Acoustics Held at the University of Birmingham on 1st and 2nd April 1971* (British Acoustical Society, London, 1972).

ISNA-4 18–19 April 1972
Buffalo, New York, USA
D. T. Blackstock, Chair

Program of the 83rd Meeting of the Acoustical Society of America, *Journal of the Acoustical Society of America*, Vol. 52, pp. 114–116 (Session B), pp. 121–123 (Session F), pp. 144–145 (Session R) (1972).

ISNA-5 20–22 August 1973
Copenhagen, Denmark
L. Bjørnø, Chair

*Finite-Amplitude Wave Effects in Fluids*, Proceedings of the 1973 Symposium, edited by L. Bjørnø (IPC Science and Technology Press Ltd, Guildford, Surrey, England, 1974).

ISNA-6 8–10 July 1975
Moscow, USSR
R. V. Khokhlov, Chair

*Proceedings of the 6th International Symposium on Nonlinear Acoustics*, Vols. 1 and 2, edited by R. V. Khokhlov (Moscow State University, Moscow, 1976).

ISNA-7 19–21 August 1976
Blacksburg, Virginia, USA
A. H. Nayfeh, Chair

*Abstracts of Papers Submitted to Seventh International Symposium on Nonlinear Acoustics*, edited by A. H. Nayfeh and J. E. Kaiser (Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1976).

ISNA-8 3–6 July 1978
Paris, France
A. Zarembowitch, Chair

8th International Symposium on Nonlinear Acoustics, *Journal de Physique*, Colloque C8, Supplément au No. 11, Tome 41 (1979).

ISNA-9 20–24 July 1981
Leeds, UK
D. G. Crighton, Chair

*Ninth International Symposium on Nonlinear Acoustics, Book of Abstracts* (University of Leeds, UK, 1981).

ISNA-10 24–28 July 1984
Kobe, Japan
A. Nakamura, Chair

*Proceedings of the 10th International Symposium on Nonlinear Acoustics*, edited by A. Nakamura (Teikohsha Press, Kadoma, Japan, 1984).

ISNA-11 24–28 August 1987
Novosibirsk, USSR
V. K. Kedrinskii, Chair

*Problems of Nonlinear Acoustics*, Proceedings of IUPAP, IUTAM Symposium on Nonlinear Acoustics, Parts I and II, edited by V. K. Kedrinskii (Siberian Division of the Academy of Sciences of the USSR, Novosibirsk, 1987).

ISNA-12 27–31 August 1990
Austin, Texas, USA
M. F. Hamilton and D. T. Blackstock, Cochairs

*Frontiers of Nonlinear Acoustics, 12th ISNA*, edited by M. F. Hamilton and D. T. Blackstock (Elsevier Applied Science, London and New York, 1990), ISBN 1-85166-537-4.

ISNA-13 28 June – 2 July 1993
Bergen, Norway
H. Hobæk, Chair

*Advances in Nonlinear Acoustics*, edited by H. Hobæk (World Scientific, Singapore, 1993), ISBN 981-02-1477-4.

ISNA-14 17–21 June 1996
Nanjing, China
R. J. Wei, Chair

*Nonlinear Acoustics in Perspective*, edited by R. J. Wei (Nanjing University Press, Nanjing, 1996), ISBN 7-305-02943-2.

ISNA-15 1–4 September 1999
Göttingen, Germany
W. Lauterborn, Chair

*Nonlinear Acoustics at the Turn of the Millennium*, edited by W. Lauterborn and T. Kurz, AIP Conference Proceedings Vol. 524 (American Institute of Physics, Melville, 2000), ISBN 1-56396-945-9.

ISNA-16 19–23 August 2002
Moscow, Russia
O. V. Rudenko and O. A. Sapozhnikov, Cochairs

*Nonlinear Acoustics at the Beginning of the 21st Century*, edited by O. V. Rudenko and O. A. Sapozhnikov, Vols. 1 and 2 (Moscow State University, Moscow, 2002), ISBN 5-8279-0034-6 (Vol. 1), 5-8279-0035-4 (Vol. 2).

ISNA-17 18–22 July 2005
State College, Pennsylvania, USA
A. A. Atchley, Chair

*Innovations in Nonlinear Acoustics* (including the International Sonic Boom Forum), edited by A. A. Atchley, V. W. Sparrow, and R. M. Keolian, AIP Conference Proceedings Vol. 838 (American Institute of Physics, Melville, 2006), ISBN 0-7354-0330-9.

ISNA-18 7–10 July 2008
Stockholm, Sweden
B. O. Enflo, Chair

*Nonlinear Acoustics—Fundamentals and Applications*, edited by B. O. Enflo, C. M. Hedberg, and L. Kari, AIP Conference Proceedings Vol. 1022 (American Institute of Physics, Melville, 2008), ISBN 978-0-7354-0544-8.